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THE SPIKE-HORNED LEAF-MINER,[1] AN ENEMY OF GRAINS AND GRASSES.

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INTRODUCTION.

The leaf-miner *Cerodonta dorsalis* Loew, although known since 1861, has not received much attention from economic entomologists, probably for the reason that to the present time, so far as known, it has not proved a serious pest, owing to the activity of its parasites and to its wide range of food plants. Although known in entomological literature as "a corn leaf-miner," it has been observed lately that the larvæ work as readily in barley, millet, wheat, and various grasses; in fact, in the rearing cages as well as in the field the leaf-miners prefer barley and millet to corn. Wheat and oats may also be included in the list of food plants, and young barley and oats infested with this species may die from the injury. Oats and barley plants infested with *Cerodonta dorsalis* present a similar appearance to those infested with *Meromyza americana* Fitch or other species of Oscinidæ, and it is possible that injury formerly attributed to the work of Meromyza was in reality the work of *C. dorsalis*.

[1] *Cerodonta dorsalis* Loew; order Diptera, family Agromyzidae.

SYNONYMY.

This species was first described by Panzer (1)[1] as *Chlorops denticornis*, it being wrongly placed in the genus Chlorops, and in the year 1835 was referred to the genus Odontocera by Macquart (2). In the year 1861 Rondani changed the generic name from Odontocera, which was preoccupied, to Cerodonta (3) (in error published "Cerodontha"). The generic name Ceratomyza was used for this leaf-miner by Schiner (4, p. 434) in 1862, this being a synonym for Cerodontha Rondani.

HISTORY OF THE SPECIES.

So far as could be ascertained from reference to specimens in the National Museum collections, and Bureau of Entomology notes, this leaf-miner was reared, by F. M. Webster, in September, 1884, for the first time in this country, from volunteer wheat plants that sprang up after harvest and near which adults had been captured earlier in the same month. It was also swept with other wheat flies from fields of growing wheat, during the period from November 13 to 15, 1884. The species was reared by Webster from mines in the leaf sheaths of young wheat, July 30, 1888; and on August 24, and again on October 12 of the same year, he reared adults from larvæ found mining the leaves of timothy. From wheat plants taken by him July 7, 1890, at La Fayette, Ind., and shipped to the Bureau of Entomology, adults were also reared by Mr. Theodore Pergande. On February 24 to 28, 1891, Webster swept it from a field of growing wheat at College Station, Tex. During the season of 1894 Dr. W. E. Britton (5), of the Connecticut Agricultural Experiment Station, reared the species from mines in the leaves of corn which was being grown under glass for vegetation experiments. During December, 1897, at Wooster, Ohio, the adults were again reared by Webster from young wheat plants. Dr. A. D. Hopkins (7) reared the fly from timothy at Morgantown, W. Va., in 1898, the larvæ doing considerable damage to this grass.

On June 26, 1905, Webster reared this species from bluegrass growing along the street parking in Aurora, Ill. Flies were reared from wheat plants collected at Lincoln, Nebr., December 9, 1904, by Geo. I. Reeves, and he swept them from young wheat at Wichita Falls, Tex., April 16, 1905. Wildermuth reared it from wheat at Groveport, Ohio, during the summer of 1909. It was sent by W. V. Reed, April 2, 1909, from Cornelia, Ga., where the larvæ were observed attacking growing rye. During 1910, adults were swept in June and July from alfalfa in fields on the college farm at Pullman, Wash., by J. A. Hyslop. In 1911 it was reared, June 9, from a pupa found in a

[1] Numbers in parentheses refer to "Bibliography," p. 17.

stem of wheat, June 1, at Nashville, Tenn., by Geo. G. Ainslie, and was reared by him the same year from mines in leaves of corn at Hurricane, Tenn. During the period from July 23 to September 7, C. N. Ainslie reared it from leaf mines in timothy collected along the banks of ditches about Ely, Nev., September 1, and also from mines in the leaves of Hordeum at Salt Lake City, Utah, during the following September, and again from the same material early in March, 1912.

During 1911 the senior author reared it from leaves of *Panicum miliaceum* at La Fayette, Ind., and followed the species o nthe same plant from June 4 to July 29, 1912, when he was transferred elsewhere, after which the work was continued throughout the remainder of the season by W. J. Phillips. This was the first attempt made to study the development of the species continuously throughout the year. During June, 1913, G. G. Ainslie found a number of mines in the leaves of corn at Nashville, Tenn. All the mines were empty save one, which contained a hymenopterous parasite of this species. On July 7, at the same place, he found a larva mining in crab grass (*Eleusine indica*), which pupated on the same day and became adult on July 17. During 1913 V. L. Wildermuth and R. N. Wilson made some observations on the life history of this species (March to November) at Tempe, Ariz. The senior author again continued his study on the life history of the species at Columbia, S. C., in 1913, from May 4, when larvæ were first found mining in the leaves of corn in the field, until June, when experiments were discontinued for the year, owing to imperfect facilities for continuing the work at that time. In May, 1914, he again took up the investigation and continued the work throughout the remainder of the year.

During February, 1914, the junior author began an investigation of this species in the San Fernando Valley of California, where it was attacking grains. Observations were later extended to the Yuma Valley, in Arizona, and San Joaquin Valley, in central California. Observations on the life history of the species were made in the laboratory at Glendale, Cal., from February to June, and at Pasadena, Cal., from July to April, 1915. Adults and parasites of this species were again reared during March and April, 1914, from mines in leaves of corn at Lakeland and Orlando, Fla., by G. G. Ainslie. Such mines were very common in leaves of corn during this time.

FOOD PLANTS.

This species breeds in a large variety of food plants belonging to the order Graminaceæ. Although it appears to be most frequently found breeding in leaves of corn and barley, it shows a decided fondness for the grasses, especially the millets (*Panicum* spp.), in which it has been found to breed very freely.

In the breeding cages at La Fayette, Ind., the variety known as hog-millet was used by the senior author as a host, and at Columbia, S. C., the variety known as golden millet was used exclusively during the hot summer months, corn in early summer, and oats and rye during late summer and fall.

At Tempe, Ariz., Wildermuth and Wilson used wheat as the host plant in their life-history studies, while at Glendale and Pasadena, Cal., the junior author used barley plants in the life-history studies of the species.

The following is a list of food plants from which adults of *Cerodonta dorsalis* have been collected or reared, showing locality, date, and by whom recorded:

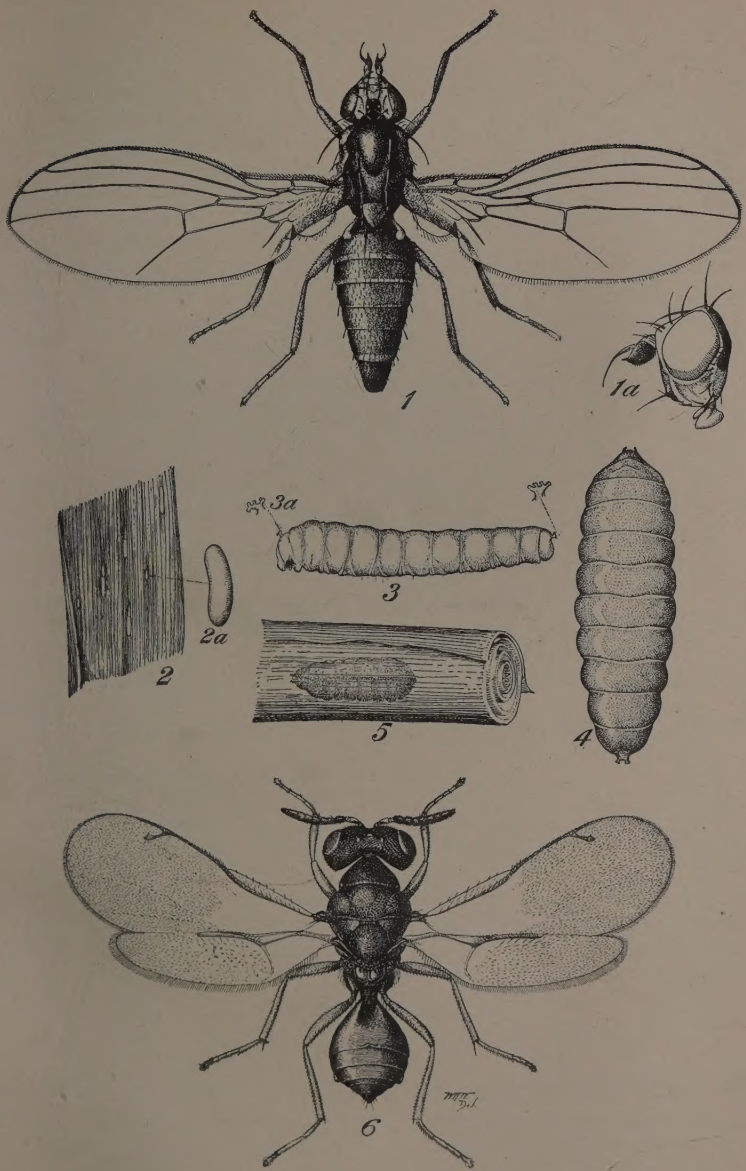
ALFALFA:
Pullman, Wash., June 9, 1910. (J. A. Hyslop.)

BARLEY:
Salt Lake City, Utah, 1911–12. (C. N. Ainslie.)
Tempe, Ariz., June 21, 1913. (R. N. Wilson.)
Glendale, Cal., February to May, 1914. (T. D. Urbahns.)
Pasadena, Cal., August, 1914, to April, 1915. (T. D. Urbahns.)
Tulare, Cal., May 15, 1914. (T. D. Urbahns.)
San Bernardino, Cal., May 27, 1914. (T. D. Urbahns.)
Santa Ana, Cal., April 10, 1915. (T. D. Urbahns.)
Heber, Cal., April 15, 1915. (T. D. Urbahns.)
Yuma, Ariz., April 16, 1915. (T. D. Urbahns.)
Bakersfield, Cal., May 22, 1915. (T. D. Urbahns.)

CORN:
Urbana, Ill., 1915. (S. A. Forbes.)
Hurricane Mills, Tenn., September, 1911. (G. G. Ainslie.)
La Fayette, Ind., 1912. (P. Luginbill.)
Columbia, S. C., 1913 and 1914. (P. Luginbill.)
Nashville, Tenn., June 10, 1913. (G. G. Ainslie.)
Lakeland and Orlando, Fla., 1914. (G. G. Ainslie.)
Glendale, Cal., May 5, 1914. (T. D. Urbahns.)
Yazoo City, Miss., May 17, 1914. (H. E. Smith.)
Greenwood, Miss., May to August, 1914. (H. E. Smith.)
Jackson, Miss., May 15, 1914. (H. E. Smith.)

EGYPTIAN MAIZE:
Glendale, Cal., June 23, 1914. (T. D. Urbahns.)

GRASSES:
Bluegrass (*Poa* sp.), Aurora, Ill., June 26, 1905. (F. M. Webster.)
Hordeum sp.—
Salt Lake City, Utah, 1911, and March, 1912. (C. N. Ainslie.)
Tempe, Ariz., June 21, 1913. (R. N. Wilson.)
Eleusine indica—
La Fayette, Ind., 1912. (P. Luginbill.)
Nashville, Tenn., July 7, 1913. (G. G. Ainslie.)
Columbia, S. C., August, 1914. (P. Luginbill.)
Hordeum murinum—
Glendale, Cal., April 13, 1914. (T. D. Urbahns.)
Elymus glaucus—
Glendale, Cal., May 3, 1914. (T. D. Urbahns.)



THE SPIKE-HORNED LEAF-MINER (CERODONTA DORSALIS).

FIG. 1.—*Cerodonta dorsalis:* Adult female, dorsal view, greatly enlarged. *1a*, Head of same, lateral view, showing tooth or horn at tip of antenna, more enlarged. FIG. 2.—Section of leaf blade showing eggs in situ and also young larvæ beginning their mines, slightly enlarged. *2a*. Egg, greatly enlarged. FIG. 3.—Larva, lateral view, much enlarged. *3a*, Anterior stigmal process, more enlarged. FIG. 4.—Puparium, dorsal view, greatly enlarged. FIG. 5.—Section of barley stem, showing usual position of puparium beneath leaf sheath. FIG. 6.—*Polycystus foersteri*, a hymenopterous parasite of *C. dorsalis;* dorsal view, very greatly enlarged. (Original.)

GRASSES—Continued.

Bromus carinatus—

Glendale, Cal., May 3, 1914. (T. D. Urbahns.)

Phalaris minor—

Glendale, Cal., June 9, 1914. (T. D. Urbahns.)

Panicum dichotomiflorum—

Owensboro, Ky., September 22, 1913. (G. G. Ainslie.)

Panicum miliaceum—

La Fayette, Ind., 1911; June 4–July 29, 1912 (P. Luginbill).

Dactylis glomerata—

La Fayette, Ind., July 23, 1913. (P. Luginbill.)

MILLET (*Panicum* sp.):

La Fayette, Ind., 1911–12. (P. Luginbill.)

Columbia, S. C., 1914. (P. Luginbill.)

OATS:

Glendale, Cal., May 3, 1914. (T. D. Urbahns.)

Pasadena, Cal., August, 1914. (E. L. Barrett.)

Columbia, S. C., October, 1914. (P. Luginbill.)

RYE:

Cornelia, Ga., April 2, 1909. (W. V. Reed.)

Columbia, S. C., October, 1914. (P. Luginbill.)

SORGHUM:

Columbia, S. C., August, 1914–15. (P. Luginbill.)

TIMOTHY:

La Fayette, Ind., August 14, 1888. (F. M. Webster.)

West Virginia, 1898. (A. D. Hopkins.)

Ely, Nev., September 1, 1911. (C. N. Ainslie.)

La Fayette, Ind., July 12, 1912. (P. Luginbill.)

WHEAT:

La Fayette, Ind., November, 1884; July, 1888; and July, 1890. (F. M. Webster.)

Oxford, Ind., September 5, 1884. (F. M. Webster.)

Lincoln, Nebr., December 8, 1904. (G. I. Reeves.)

Wichita Falls, Tex., April 16, 1905. (G. I. Reeves.)

Groveport, Ohio, date unknown. (V. L. Wildermuth.)

Nashville, Tenn., June 9, 1911. (G. G. Ainslie.)

Tempe, Ariz., March to June, 1913. (Wildermuth and Wilson.)

Elk Point, S. Dak., July 8, 1913. (C. N. Ainslie.)

Visalia, Cal., May 15, 1914. (T. D. Urbahns.)

Tulare, Cal., May 16, 1914. (T. D. Urbahns.)

DESCRIPTION.

THE ADULT.

Cerodonta dorsalis (Pl. I, fig. 1) was redescribed by Mr. J. R. Malloch (14, p. 331), then assistant in the Bureau of Entomology. The description is as follows:

Male and female: Frons yellow, opaque, in breadth about one-half that of head; orbits sometimes blackened, very narrow, on upper half each not over one-sixth as wide as center stripe; three distinct orbital bristles present, and on lower portions a few short hairs; proclinate ocellar bristles parallel, or slightly divergent, separated at base by as wide a space as posterior ocelli; antennæ yellow, third joint black, one and one-half times as long as broad ending in a

thorn-like point on upper side; arista black, distinctly thickened at base and tapering to near its middle, pubescence indistinguishable, length of arista short of twice the length of antennæ; face yellow, slightly concave, central keel rounded; cheeks yellow, higher posteriorly than anteriorly, and at highest point about one-half as high as eye, marginal bristles distinct; vibrissa strong, differentiated from marginal bristles; proboscis and palpi yellow; occiput unprojecting on upper half. Mesonotum with disk entirely glossy black, with sometimes an indication of grayish pollen, or with the central portion in front of scutellum yellow, more rarely with two narrow black stripes on sides, and the central yellow portion carried forward at its anterior margin, slightly beyond middle, as narrow lines which more or less distinctly intersect the broad discal black mark, giving the disk the appearance of having five stripes, or a pattern somewhat similar to that of *Agromyza melampyga;* lateral margins of mesonotum broadly yellow; humeri with a black spot; four pairs of dorso-central bristles on mesonotum; no setulæ on disk; pleuræ yellow with black variegations; squamæ yellow, the fringe brownish or grayish; scutellum all black or with the disk yellow, two scutellar bristles present. Abdomen from almost entirely yellow to almost entirely black, posterior margins of segments narrowly yellow. Legs slender, yellow, sometimes with fore tibiæ and tarsi blackened, all tarsi brownish. Wings as figure.

Length 2–2.5 mm.

The stages of this species are as follows:[1]

THE EGG.

(Pl. I, fig. 2, *a*.)

Egg elongate kidney-shaped, rounded at each end. Color opaque white, without distinct punctation, markings, or ornamentation of any kind. Two or three days after deposition the embryo, as seen through the chorion, shows 14 segments.

Length 0.40 mm; diameter 0.18 mm.

THE LARVA.

(Pl. I, fig. 3, and Pl. II, figs. 1 and 2.)

Length 4 mm; greatest diameter 0.75 mm. Slender, nearly cylindrical, slightly thicker near cephalic end, which is obtusely pointed. Mouth-hooks black and exposed to view when at rest. Body segments plainly defined, armed at either end near sutures with slender areas of microscopic spinous processes. Anal extremity abruptly truncate and bearing the spiracular appendages close to the dorsal line. Anterior stigmatal projections plainly visible and formed as in figure 3, a. Color of body in life dirty white, the surface of the skin having a distinct gloss, as shown in figures 7 and 8; after death and preserved in alcohol, opaque, nearly white.

THE PUPA.

(Pl. I, fig. 4.)

Pupa somewhat elongate, flattened dorso-ventrally. White when freshly formed, turning yellow and growing darker as pupa advances in development. Cephalic end obtusely conical; posterior end more rounded. Segments strongly constricted at sutures. Stigmatal processes, both anterior and posterior, distinctly projecting. Length 2.5 to 3 mm.; lateral diameter about 1 mm.; dorso-ventral diameter 0.60 mm. to 0.70 mm.

[1] The descriptions were written by W. R. Walton.

DISTRIBUTION.

This species has a wide range of distribution within the United States (fig. 1). It is known to occur from Indiana and Ohio in the North to southern Florida in the South, and from Massachusetts in the East to Washington, California, and New Mexico in the West. It is probably to be found wherever its food plants thrive. Outside of the United States it has been collected from Porto Rico and Mexico.

The following localities and other data have been compiled from pinned specimens of this species in the United States National Museum collection: Beverly, Mass., August, 1911 (Burgess); Las Vegas,

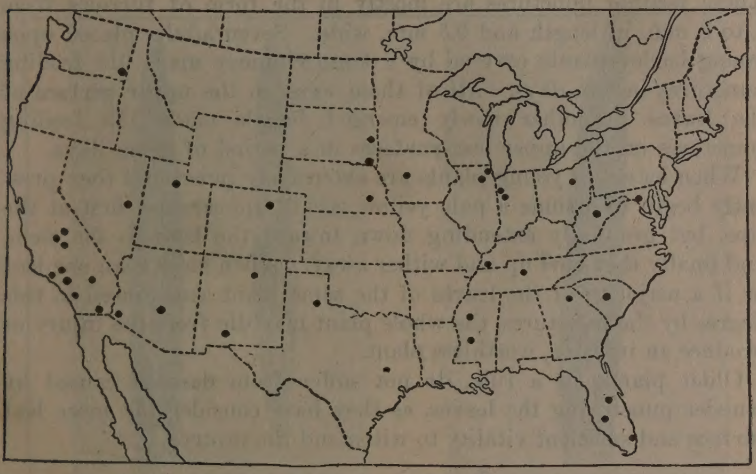


FIG. 1.—Map showing records of distribution of the spike-horned leaf-miner (*Cerodonta dorsalis*) in the United States. (Original.)

N. Mex. (H. S. Barber); Ames, Iowa, June, 1877; Orizaba, N. Mex., January (H. Osborn); Colorado; High Island, Md., May, 1898 (Currie); New York, July, 1898; Arroyo, Porto Rico, February, 1899 (Busck); District of Columbia; Claremont, Cal. (Baker); Biscayne, Fla. (A. Slosson).

INJURY TO PLANTS BY ADULTS PUNCTURING THE LEAVES.

The punctures made by the females of this species in leaves of plants on which they feed and oviposit (Pl. II, fig. 3) resemble very closely those made by females of *Agromyza parvicornis* Loew, with the exception that they are frequently somewhat longer and a trifle narrower. Some of the punctures are twice as long as others. The punctures are not made solely as receptacles in which to deposit eggs, but apparently primarily as a means of acquiring access to the

sap of the leaves upon which the adults subsist. Only a very small proportion of the punctures are utilized as receptacles for eggs, which fact would indicate that they are made for feeding purposes rather than for oviposition.

As a general rule, the punctures are made from the upper side, in the tenderest portions of the leaves of recent growth. Sometimes, however, punctures may be found even in the upper part of the tender stems, especially in the case of young plants.

The female adult of this species apparently first scars the leaf surface with her ovipositor. Then, as the sap begins to escape from this wound, the insect proceeds to feed and, with a rasping movement of the mouth parts, digs little furrows between the leaf veins. These feeding punctures are mostly in the form of furrows from 1 to 3 mm. in length and 0.5 mm. wide. Seven adults placed upon young barley plants covered by a lamp chimney made 918 feeding punctures in five days. All of these were on the upper surface of the leaves. Another newly emerged female made 133 feeding punctures on the upper leaf surfaces in a period of seven days.

When leaves of young plants are extensively punctured they presently begin to assume a pale yellow, sickly appearance, first at the tips, but gradually extending down toward the base to the stem, and finally they curl up and wither away. When more than one leaf or if a majority of the leaves of the same plant are injured to this degree by the punctures, the whole plant may die from the injury or produce an inferior, worthless plant.

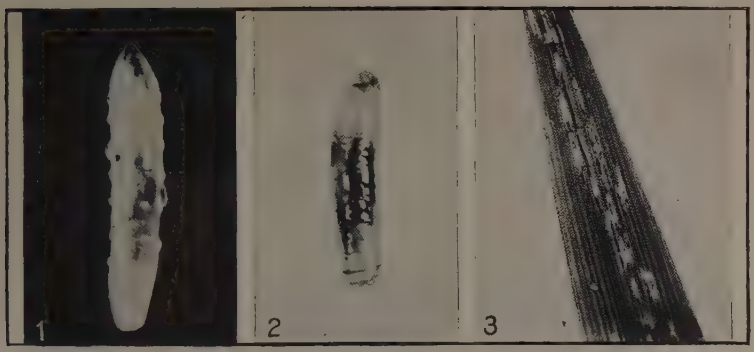
Older plants, as a rule, do not suffer from damage caused by females puncturing the leaves, as they have considerably more leaf surface and sufficient vitality to withstand the injury.

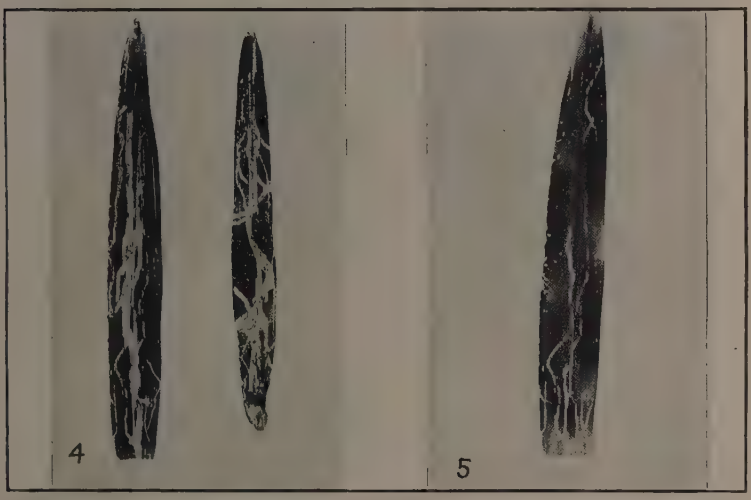
INJURY TO PLANTS BY MINING HABITS OF LARVÆ.

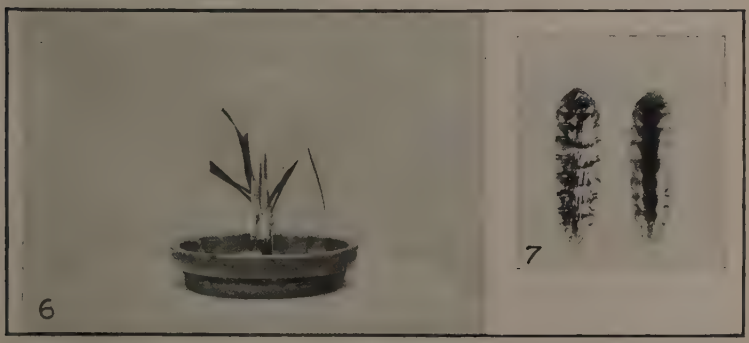
This species has been found to be most destructive in the larval stage, mining in the leaves and sometimes in the stems of young tender plants having only a limited area of leaf surface. Mines started in the leaves of such young plants are often continued down into the heart after reaching the base of the leaf to a point near or slightly below the surface of the ground before the larvæ reach maturity and their ravages cease. The leaves arising from the bud having been severed, they dry up, and the whole plant presents an appearance as though infested with the wheat bulb-worm (*Meromyza americana* Fitch) or some species of the genus Oscinis.

Young tender oat plants about 3 inches tall, having from three to four leaves, were found by the senior author to be injured in this manner in a small patch of oats at Columbia, S. C., in the fall of 1914.

The larvæ of *C. dorsalis* have been observed by the junior author causing much injury to small barley plants in the fields in several







THE SPIKE-HORNED LEAF-MINER (CERODONTA DORSALIS).

FIG. 1.—Larva, dorsal view. Photographed from life. The young larva of an external hymenopterous parasite may be seen attached to middle of larva of Cerodonta on the right, much enlarged. FIG. 2.—Larva, lateral view, from life, showing polished surface and contents of alimentary canal, much enlarged. FIG. 3.—Tip of barley leaf, showing feeding punctures made by adult fly, much enlarged. FIG. 4.—Leaf blades showing advanced work of the larvæ, about natural size. FIG. 5.—Leaf blade, showing mines of young larvæ, about natural size. FIG. 6.—Type of rearing cage used in rearing the larvæ of *C. dorsalis*. FIG. 7.—Puparia, dorsal and ventral views, much enlarged. (Original.)

localities of southern California. The larva, hatching from an egg deposited near the tip of the leaf blade, begins burrowing between the upper and lower epidermal layers of the leaf.

During its first day in that stage it makes a burrow from 5 to 17 mm. in length, directed toward the base of the leaf. After two or three days of burrowing it frequently pursues a zigzag course within the leaf, thereby cutting off the sap supply. In the course of about four days the length of the burrow may reach from 4 to 6 inches. The larvæ soon enter the leaf sheath and in small tender plants burrow into the center of the stem, killing that particular stool or the entire plant.

Up to the present time this species has never been recorded as a serious pest of agricultural crops. The most severely infested field observed by the junior author was one of barley at Yuma, Ariz., on April 16, 1915, in which about 5 per cent of the plants had one or more of the leaves mined by larvæ of Cerodonta.

At Tulare, Cal., both wheat and barley fields showed that about 2 per cent of the plants were infested by this species on May 16, 1914.

In older plants, with more leaf surface and less tender stems, the larvæ, after reaching the base of the leaf, will not enter the stems, but proceed down the sheath. The hearts of such plants are not injured, and consequently the damage inflicted is very small in comparison with that upon young tender plants. However, if a plant has a number of larvæ mining in the leaves, considerable injury may be done. The mines traversing the leaves from tip to base (Pl. II, fig. 4), from one side to the other, have a tendency to interfere with the sap flow of the leaves, which eventually turn yellow and die. In long leaves, such as those of older corn plants, the mines in the leaves frequently reach from 15 to 20 inches in length before the larva is fully developed.

LIFE HISTORY.

OVIPOSITION.

The act of oviposition has been observed upon the leaves of millet by the senior author at Columbia, S. C.; upon wheat by Wildermuth, at Tempe, Ariz.; and upon barley by the junior author at Glendale, Cal. The general method of oviposition is very similar on these three different food plants.

The female fly selects a suitable place for oviposition, usually near the tip of the leaf or along the edge. With head elevated and tip of abdomen lowered, the body is held almost perpendicular to the leaf surface, and by rapid piercing movements of the abdomen the epidermal leaf tissue is punctured. The ovipositor is then forced by repeated thrusts to its full length between the upper and lower layers of the leaf, the egg quickly deposited, and the ovipositor withdrawn

to its normal position. The time occupied in oviposition varies from 10 seconds to 1 minute. The entrance to the puncture appears to be left open, although frequently the epidermal tissue about the puncture collapses, partly closing it.

Only one egg is deposited in a puncture, but the fly repeats the process of oviposition a number of times in a given day. Frequently she oviposits into what are apparently small feeding punctures.

The eggs of this species are not as easily detected by the naked eye as are those of *Agromyza parvicornis* in corn, and *A. angulata* Loew in timothy. They are more of a pale white than the eggs of either of the other species and, consequently, are not so conspicuous against the background.

The flies feed and oviposit during all hours of the day. The majority of the eggs, however, are deposited between the hours of 11 a. m. and 4 p. m. during the time the adults are most active.

Eggs may be deposited either from the upper or lower side of the leaves, but the majority of them are deposited from the upper side. They are placed with the longer axis of the egg parallel to the veins of the leaves, as are the eggs of *Agromyza angulata* and *A. parvicornis*. (Pl. I, fig. 2, shows an egg in situ in leaf.)

In the rearing cages eggs are deposited at or near the tips of the leaves, along the margins, near or at the base, in the sheaths, and sometimes in the upper part of the tender stems, especially in young plants. In nature the eggs apparently are deposited at or near the tips of leaves or along the margins of the lower leaves, as mines invariably are found to start from one of these points.

EGGS DEPOSITED BY ONE INDIVIDUAL.

The females of this species, if they have been fertilized, begin to oviposit in from one to six days after emerging from puparia; if unfertilized, they do not usually oviposit.

The laboratory observations of the senior author, made at Columbia, S. C., showed that a single individual deposited as many as 24 eggs in leaves of millet within a period of 24 hours. On an average, nine eggs were deposited per day. The rate of oviposition varied greatly and ranged from one or two eggs on a given day to as many as 15 or 20 eggs on the following day. The maximum number during the life of an individual was 188 eggs, and the longest period of oviposition covered by one individual was 33 days.

At Tempe, Ariz., Mr. Wildermuth recorded 105 eggs deposited by a single individual in leaves of wheat in a period of 10 days. The greatest number deposited in a single day was 27 eggs.

In California the observations of the junior author showed 61 eggs deposited in leaves of barley plants during the life of one individual.

From the observations made in widely separated localities by both the senior and junior authors, it appears that about 60 per cent of the eggs deposited are fertile.

EGGS DEPOSITED IN ONE LEAF AND ONE PLANT.

In our breeding experiments at Columbia, S. C., 28 eggs have been found in a single leaf of millet 6 inches tall, and as many as 50 eggs in an 8-leaved plant; 39 in a 6-leaved plant; and 99 in a 9-leaved plant. It can be seen very readily that even in case some of the eggs are infertile or for other reasons do not hatch, the plants thus heavily infested will be completely destroyed by the larvæ.

INCUBATION OF EGGS.

At Tempe, Ariz., Mr. Wildermuth's records made during the month of April showed the period of incubation to vary from 5 to 9 days, with an average of about 6 days. At Columbia, S. C., the senior author's observations during July and August showed this period to vary from 3 to 5 days, with an average of about 3½ days; one egg, however, was found to hatch in 54 hours (2.2 days). In the fall this period was found to vary from 4 to 8 days, with an average of about 5 days. At Glendale, Cal., the junior author made observations during the month of March which extended this period from 7 to 12 days, with an average of 10½ days. Observations continued during both winter and summer months at Glendale and Pasadena, Cal., showed the incubation period to vary from 5 to 12 days, with an average of about 7 days. This period is without doubt somewhat shorter in the open fields where infested plants are subjected to refracted heat.

LARVAL HABITS.

The larva, when ready to emerge, ruptures the cephalic end of the eggshell, as do the larvæ of *Argromyza angulata* and *A. parvicornis*, and immediately begins to feed on the green tissues of the leaf. The mine at first is very small and threadlike, scarcely noticeable to the unaided eye. (Pl. II, fig. 5.) The diameter of the mine increases as the larva increases in size, and by the time the larva reaches maturity the mine may be greatly widened. In large plants, with long, wide leaves, the larvæ frequently make mines from 15 to 20 inches in length. Such mines are usually linear in outline, and although they run from side to side, the turns are less frequent than when larvæ mine in short leaves of smaller plants. In the latter the larvæ traverse the leaves oftener. They frequently make side galleries diagonally across the leaves, then retreat and continue the main mine down the blade.

A number of these galleries are often found leading away from one mine in a leaf. All sorts of peculiarly shaped mines are made in leaves, especially in small plants or in plants with a limited amount of leaf surface. Some of these mines show almost perfect loops, while others traverse the leaves in snakelike fashion.

In young oats and barley the larvæ apparently break away from the accustomed habit of making threadlike mines and instead appear to undermine almost the entire upper surface of the leaves in which they are feeding. As a result the leaves dry up (Pl. II, fig. 4).

The larvæ of this species pupate in the mines, usually in the leaf sheath (Pl. I, fig. 5). The adult, upon emerging from the puparium, tears open the dry tissue at or near the pupal case and makes its escape.

LENGTH OF LARVAL STAGE.

The average length of the larval stage in the latitude of Columbia, S. C., is 10 days during midsummer or in seasons of high temperatures. This period is considerably longer in spring, and much longer in late fall, ranging from 9 to 24 days during different seasons and in different localities.

Larvæ hatching from eggs about the middle of October were overtaken by frost and killed the second week in November. Larvæ hatching from eggs deposited the same day by the same fly sometimes show a difference of three days in their total period of larval development. The difference is apparently caused by a deficiency in the immediate supply of food, which forces the larva to mine a greater area to satisfy its demand, and as a result the duration of the period of larval development is lengthened.

LENGTH OF PUPAL STAGE.

The length of the pupal stage (Pl. I, fig. 4; Pl. II, fig. 7) of this insect varies from 9 to 12 days during midsummer and from 11 to 16 days during spring and late fall in the latitude of Columbia, S. C.

A short pupal period of eight days during July is recorded by G. G. Ainslie at Nashville, Tenn., and a pupal period of from 14 to 18 days by V. L. Wildermuth at Tempe, Ariz., during March and April. At Pasadena, Cal., the pupal period ranges from 12 to 24 days at different seasons of the year.

LIFE AND HABITS OF ADULTS.

Flies begin to issue from puparia during the latter part of May in the latitude of La Fayette, Ind., but probably considerably earlier at Columbia, S. C., as adults in breeding cages began to issue in February of 1915. These, however, died within a short time and without reproducing. In the vicinity of Pasadena, Cal., adults of

this species are active throughout the entire year, appearing in abundant numbers over the grain fields during the months of February, March, and April. The males do not live quite as long in the rearing cages as do the females. They may live from eight days to four weeks, but generally not over two weeks. The females may live from three to five weeks and oviposit during most of this time. This long period of oviposition accounts for the complete overlapping of the broods. The first progeny may have progressed to the pupal stage some days before the last eggs of its mother have been deposited. The females live only from three to five days after they cease to oviposit.

The flies appear the most active when the temperature ranges between 85 and 95 degrees F., and when below 70 degrees they become sluggish in their movements, especially so in flight.

Adults are fond of sweets and lived for a longer period in cages supplied with a quantity of sugar solution than in cages not so provided.

MATING.

Adults generally begin to mate the second or third day after emergence; sometimes mating occurs on the day of issuance. They apparently mate several times during life. They remain in copula from a few seconds to thirty minutes or more. The female is able to fly about while in coitu with the male, the added weight being apparently no great hindrance in flight.

NUMBER OF GENERATIONS.

According to the rearing experiments conducted by the senior author at La Fayette, Ind., there are at least three generations from about the middle of May to the first of October, after which the species goes into hibernation. He found apparently six generations in the latitude of Columbia, S. C. Many of the larvæ of the last generation at both places did not reach maturity. Some died upon maturity of the plants and others were killed by frost.

Rearing experiments in the vicinity of Pasadena, Cal., show that there are at least eight generations of this insect throughout the year.

The first and second generations are generally well defined, but the others overlap completely, so that all stages of the insect may be present at one time. In southern California it may be found in all stages throughout the entire winter.

LIFE CYCLE.

The average life cycle in the vicinity of Pasadena, Cal., is considerably longer than in the vicinity of Columbia, S. C., because in the former locality the insect reproduces throughout the winter months, when the stages are very slow in development. The average

period elapsing between the different stages throughout the year in the vicinity of Pasadena is as follows:

	Days.
Period between emergence of adult and oviposition	3
Egg stage	7
Larval stage	16
Pupal stage	18
Average life cycle	44

Observations made at Columbia, S. C., from June to August, 1914, showed the stages and life cycle as follows:

	Days.
Period between emergence and oviposition	3
Egg stage	3.5
Larval stage	10
Pupal stage	10
Total life cycle	26.5

Wildermuth obtained the following life cycle of this species at Tempe, Ariz., during April and May in 1913:

	Days.
Period between emergence and oviposition	4
Egg stage	3.5
Larval stage	12
Pupal stage	16
Total life cycle	37.5

HIBERNATION.

This species has apparently no distinct period of hibernation in the warm climate of southern California, but the different stages are naturally considerably retarded in their development during the cold days of winter.

In the latitude of Columbia, S. C., and La Fayette, Ind., the species hibernates in the pupal stage. The first heavy freeze killed the adults, larvæ, and the plants in rearing cages at Columbia, S. C. An infested field of oats at Columbia revealed only puparia throughout the greater part of the winter.

REARING METHODS.

The rearing cages found to be the most satisfactory by the senior author in his study of the life history of this species, both at La Fayette, Ind., and Columbia, S. C., consisted of 12-inch flowerpots containing food plants and covered with cylinders made of celluloid and galvanized iron. The tops of these cylinders were covered with cheesecloth. Moist food was kept in the cages for the adults.

The junior author in his study of this species in California found that cages made of wire arches and cheesecloth bags gave the best results. The type of cage used by him for observations on feeding

and oviposition consisted of a lantern chimney covered with cheesecloth and placed over a small potted plant (Pl. II, fig. 6). A lump of sugar moistened with water was placed in the bottom of the cage. The senior author in his study of the oviposition and feeding habits used a cage consisting of a small lantern chimney placed in an earthen saucer. Inside of the lantern chimney was placed a bottle containing a small millet plant in water; these plants were afterward potted. Moistened sugar was also placed in this cage. It was found that adults in the small cages lived for a longer period than in the larger rearing cages, probably on account of having access more readily to food given them.

PARASITIC ENEMIES.

The important natural enemies of this leaf-miner are parasitic Hymenoptera, of which the species named below have been reared. Some of these have been reared at widely separated localities and from their host working upon different food plants. These parasites become active in early spring, increasing in abundance with each succeeding generation, until their activity is retarded by the approach of cold weather.

It may be possible that the almost total disappearance of the host during midsummer in some localities is due to the effective work of some of these parasites, the life histories of which have not been worked out.

Cirrospilus flavoviridis Cwfd.—This species was reared from a mine of *C. dorsalis* in a timothy leaf taken at Ely, Nev., by C. N. Ainslie. It is also a parasite of the leaf-miners *Agromyza pusilla* Meig. and *A. parvicornis*.

Cyrtogaster occidentalis Ashm.—This species was reared by the junior author, on May 9, 11, and 18, 1914, from puparia of *C. dorsalis*, taken from barley leaves at Yuma, Ariz., and again on June 3, 1914, from a puparium which was removed from a leaf of wheat taken at Tulare, Cal. During 1913 the senior author reared it from *C. dorsalis* mines in corn at Columbia, S. C. G. G. Ainslie reared it on May 11, 1914, from *C. dorsalis* mines in corn at Lakeland, Fla., and H. E. Smith reared it May 25, 1914. from mines of this species in corn at Greenwood, Miss.

Diaulinus websteri Cwfd.—This parasite was reared in December, 1914, by E. L. Barrett from larvæ of *C. dorsalis* working in barley at Pasadena, Cal. The species was described by Crawford[1] (p. 184) from specimens recorded from Tempe, Ariz., under Webster No. 7286.

Diaulinopsis callichroma Cwfd.—This species was also reared from *C. dorsalis* larvæ working in corn, first by G. G. Ainslie at

[1] Crawford, J. C. Descriptions of new Hymenoptera. *In* Proc. U. S. Nat. Mus., v. 43, p. 163–188. 1912.

Lakeland, Fla., in May, 1913, and by H. E. Smith at Greenwood, Miss., in May, 1914. The species was described by Crawford[1] (p. 183) from specimens under Webster No. 7286, Tempe, Ariz.

Polycystus foersteri Cwfd. (Pl. I, fig. 6).—This species was reared from *C. dorsalis* in corn by G. G. Ainslie, May, 1913, at Orlando, Fla., and was reared from *C. dorsalis* in barley by E. L. Barrett at Pasadena, Cal., on June 6, 1915. This parasite was described as a new species by Crawford (Proc. U. S. Nat. Mus., v. 45, p. 313) in 1912, from specimens reared by the senior author from *Agromyza angulata* at La Fayette, Ind.

Dacnusa n. sp.—This species was reared April 25, 1914, from a puparium of *C. dorsalis* removed from *Hordeum murinum* taken at Glendale, Cal., and on May 1 and 2, 1914, it emerged from puparia of *Cerodonta dorsalis* removed from barley at the same locality. It was reared on January 3, 1915, by E. L. Barrett from a puparium of *C. dorsalis* removed from a barley leaf at Pasadena, Cal.

Chrysocharus parksi Cwfd.—This species was reared by T. D. Urbahns, the junior author, June 16, 1914, from a puparium of *C. dorsalis* removed from a leaf of wheat taken at Visalia, Cal. The species was described by Crawford[1] (p. 173).

Opius dimidiatus Ashm.—The senior author reared one adult of this species from *C. dorsalis* mines in millet at La Fayette, Ind., in 1912. This species is also recorded as a parasite of *A. pusilla*.[2]

Opius aridus Gahan.—Mr. G. G. Ainslie reared this species from mines of *C. dorsalis* in corn at Lakeland, Fla. This species is also an enemy of *Agromyza pusilla*.[3]

PREVENTIVE MEASURES.

Owing to the concealed character of damage and method of working, this insect has not attracted widespread attention, and no demands have been made concerning control methods. It would appear, however, that the practice of summer fallowing in the West would do much to destroy puparia remaining in the dry leaves.

Fall plowing and, in fact, any thorough cultivation of grain fields to destroy the remaining stems and leaves as well as volunteer grain should destroy such of this species as remain in the larval and pupal stages.

Burning of dry grasses along fence lines, roadsides, and terraces in late fall and early spring should likewise destroy some of the puparia.

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